Relationships between Asynchronous / Synchronous Online Lecture Engagement and Low-stake Assessments: Lessons from Online Flipped Undergraduate Classrooms during COVID-19.

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Abstract.

When choosing to deliver a program or module online, whether to deliver synchronously or asynchronously is pertinent. While both approaches have intrinsic limitations, a common challenge is maintaining online student engagement. With increased post-pandemic implementation of online / blended delivery across higher education, means of increasing online student engagement must be prioritized, furthermore whether to rely solely on synchronous or asynchronous delivery for such courses must be addressed. In our study, we describe student feedback on how such engagement might be enhanced for online delivery. We outline the implementation of an online, flipped classroom for a 3rd year Pharmaceutical Biotechnology module (34 students) at Dundalk Institute of Technology (DkIT), during COVID-19. Classes consisted of 2 hours delivered asynchronously (via recorded lectures) and a 3rd hour for synchronous active learning over MS Teams. We found that engagement with online recorded lectures (number of video views/student each week) was positively correlated with increased performance in weekly low-stake assessments (10 x online MCQs, 1% of total grade) and final exam scores. Four students relayed their experiences at the end of the semester in an anonymous focus group and reported; 1. Asynchronous delivery enabled flexible learning and self-pacing, with ability to replay lectures a noted benefit. 2. Synchronous learning allowed class interaction, instructor feedback and knowledge application. 3. Combination of asynchronous and synchronous approaches was preferred over a single delivery mode. 4. Synchronous sessions and low-stake weekly assessments incentivized engagement with asynchronous class materials. While our findings are preliminary, due to the low number of students (4/34) that contributed to our focus group, our data does suggest that combining asynchronous and synchronous resources and low-stake assessments might enhance student engagement with online asynchronous resources. These findings have pedagogical implications for educators designing future modules or programmes for online delivery.

Keywords: Assessment; Asynchronous; Flipped classroom; Online Lecture; Student engagement.

1. Introduction.

1.1 Engagement in Online Education: Should We Use Synchronous or Asynchronous Delivery?

When choosing to deliver an educational program online, a key decision is whether to deliver the course synchronously or asynchronously. Synchronous delivery involves live delivery of online classes such as lectures, tutorials, workshops or discussion groups, via a virtual learning environment (VLE) or videoconferencing software such as Zoom, Microsoft (MS) Teams or Big Blue Button (Hrastinski, 2008). In contrast, in asynchronous delivery, students access prepared content via a VLE and progress through the material in their own time (Hrastinski, 2008). With increased post-pandemic implementation of online / blended delivery across higher education, means of increasing online student engagement must be prioritized, furthermore whether to rely solely on synchronous or asynchronous delivery for such courses must be addressed.

Even prior to the rapid changes brought about by COVID-19 restrictions, 3rd level educators were experimenting with blended online / face-to-face courses or entirely online delivery of certain programs in all fields (de Jong, Verstegen, Tan, & O'Connor, 2013; Gadbury-Amyot & Brockman, 2011; Kunin, Julliard, & Rodriguez, 2014; See, 2017; Shang & Liu, 2018). While some have argued (including students) that online teaching can never fully replace face-to-face learning (See, 2017; Simcock, Chua, Hekman, Levin, & Brown, 2017) and that online environments lack vital instructor-student and student-student interactions (Gadbury-Amyot & Brockman, 2011; Schoenfeld-Tacher & Dorman, 2021), the nascent experiences of many 3rd level educators emerging from 2-years of online teaching implores us to examine what lessons and tools picked up during the pandemic might be used in future curriculum delivery and design.

Both synchronous and asynchronous approaches have intrinsic limitations and disadvantages. For synchronous online delivery, both students and instructors require adequate internet connectivity and hardware to make routine synchronous delivery feasible (Bixler et al., 2021; Holzmann-Littig et al., 2022). A major issue with both synchronous and asynchronous online delivery is maintaining student engagement (Evans, Knight, Sonderlund, & Tooley, 2014). While increasing student engagement with online learning can be challenging with any approach, it has been noted in several studies that engagement is significantly lower in solely asynchronous delivery (Gadbury-Amyot & Brockman, 2011; Kunin et al., 2014; Schoenfeld-Tacher & Dorman, 2021).

The effectiveness of one mode over the other on academic performance or on student perceptions can vary considerably among different student groups (Chen, van Reyk, Reyna, & Oliver, 2022). In a study with 2nd year veterinary students, there was no statistical difference between academic performance when lectures were delivered asynchronously or when lectures took place in a traditional classroom setting, although lack of instructor interactions was noted as a barrier to learning in the former (Schoenfeld-Tacher & Dorman, 2021). Similarly, in an undergraduate pharmacotherapy course comparing asynchronous and synchronous video delivery of lectures, there was no difference in summative scores using either method (Moridani, 2007). Similar trends have been observed in both Masters level courses (Farros, Shawler, Gatzunis, & Weiss, 2020) and in nursing students (Suliman, Ta'an, Abdalrhim, Tawalbeh, & Aljezawi, 2022), which found no difference in academic performance across synchronous and asynchronous modes.

1.2 Can We Combine the Benefits of Online Synchronous and Asynchronous Delivery? Do Low-stake Assessments Help?

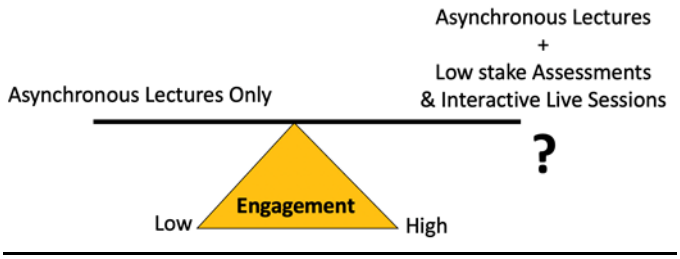
Many instructors have attempted to reconcile the positive and negative aspects of online synchronous and asynchronous delivery by integrating the two approaches into a flipped classroom model. Flipped classrooms are a student focused teaching and learning strategy that seeks to enhance active learning (Sultan, 2018). In flipped classrooms, students are provided with class materials before class and spend their entire live class time engaging in group work, exercises, workshops, discussions or other active learning methodologies (Nouri, 2016). Thus, class time is dedicated solely to active learning with course '*coverage*' being self-directed by students. Flipped classrooms are associated with enhanced academic performance, increased student engagement and are noted to encourage attendance (Drumm, 2023; Gopalan, Daughrity, & Hackmann, 2022; Hernandez-Guerra et al., 2021; Nouri, 2016; Sultan, 2018). In the online space, several studies show that flipped classrooms, where students engage with asynchronous content in their own time before participating in a synchronous active learning centered class, has been positively received by students (Beason-Abmayr, Caprette, & Gopalan, 2021; Chesterton, Richardson, & Tears, 2022; Fogg & Maki, 2021; Gopalan, Butts-Wilmsmeyer, & Moran, 2021).

In this paper, we describe the implementation of an online, flipped classroom for a 3rd year Pharmaceutical Biotechnology module (within a Bioscience / Biopharmaceutical Science BSc program) at Dundalk Institute of Technology (DKIT) in semester 1 of 2020, during COVID-19

enforced restrictions on face-to-face teaching. In this model, classes consisted of 3 contact hours per week. 2 hours would be delivered asynchronously with the 3rd hour dedicated to synchronous active learning exercises (often in small groups) facilitated over MS Teams. In contrast to the initial ad hoc pivot to emergency remote teaching (March 2020), where this module was taught solely via asynchronous pre-recorded videos (Drumm & Jong, 2020), the design of online delivery from September to December 2020 was based on published literature from the onset of the pandemic. This literature suggested that a mix of synchronous and asynchronous delivery was optimum for online undergraduate course delivery (Nieuwodt, 2020; Northey, 2015; Rapanta, 2020). This decision was also informed by previous students who undertook the solely asynchronous module in March – May 2020, who noted that a mixture of live and recorded classes might increase student engagement with the module (Drumm & Jong, 2020).

A specific suggestion to enhance engagement from this previous student feedback was to utilise low-stake assessments (such as a short quiz) to incentivise students to progress through asynchronous materials (Drumm & Jong, 2020). We therefore included a weekly, low-stake MCQ quiz on the asynchronous content of the module as part of our integrated online flipped classroom. We initially hypothesised that in comparison with solely asynchronous delivery, students would report increased module engagement when it also included regular low-stakes assessments and interactive synchronous sessions (Fig. 1). We analyzed how student engagement with asynchronous lectures changed as the semester progressed and determined the correlation between asynchronous engagement and scores in both weekly low-stake assessments (MCQs) and the summative final exam. In order to determine the motivations behind engagement with asynchronous materials, at the end of the semester, we invited students to participate in an anonymous, online focus group to discuss how various factors affected engagement (including the low-stake assessments, participation in active synchronous classes). We summarize our findings and draw conclusions that relate to future online and flipped classroom design.

Figure 1: Hypothesis



Regular low stake assessments and synchronous live sessions, in combination with asynchronous, pre-recorded lectures will increase student participation in a module compared to solely asynchronous delivery.

2. Methods.

2.1 Ethics.

All procedures and analysis were approved by DkIT School of Health & Science Research Ethics Committee.

2.2 Module Description.

The online flipped classroom took place within a 3rd year module '*Pharmaceutical Biotechnology*', taken from September to December 2020. This module sits within the DKIT Level 7 programmes in Pharmaceutical Science and Bioscience and the Lv8 programme in Biopharmaceutical Science. This specific cohort consisted of 34 students. The module constituted 3 class contact hours per week (not including practical laboratory sessions). In this instance, all 3 contact hours were timetabled to take place sequentially, on Friday mornings from 09.00 – 12.00.

2.3 Flipped Classroom Model.

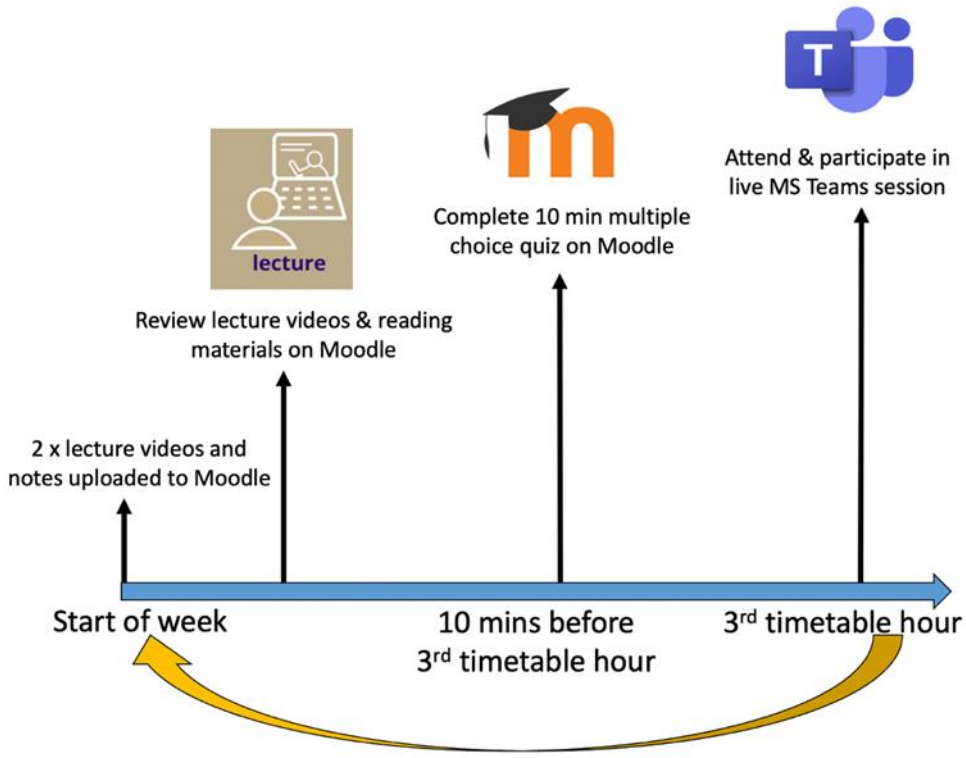
For our mixed asynchronous and synchronous model, 2 hours of pre-recorded lectures (as narrated PowerPoint decks) were uploaded to the VLE Moodle as YouTube videos. A dedicated and private YouTube channel was established for storing all module videos. Each video began with a short welcome and summary from the lecturer (2-3 minutes) and concluded with a 5 –10-minute overview of specific active learning outcomes from each class. The total length of the video, including coverage of new content never exceeded 55 minutes. A PDF copy of the

PowerPoint slides were also provided to students on Moodle. In certain weeks, articles and book chapters relevant to that week's material were uploaded to an '*outside reading*' section on the module page in Moodle. Students were informed at the beginning of the semester via a live MS Teams session with the lecturer that the module would be delivered via a flipped model and that live classes would be application based, taking place during the final timetabled hour for the module each week (11.00 – 12.00). Students were advised they could make their way through asynchronous material in their own time, but they could use the timetabled hours for the module to help structure their own pacing.

Asynchronous materials were uploaded to Moodle at least 5 days prior to each live class and students were notified of new uploads via Moodle and email. Students were asked to complete a 10-minute multiple choice quiz (MCQ) on each week's asynchronous materials before the synchronous live session on MS Teams (Fig. 2). There were 10 MCQ quizzes in total throughout the semester and each quiz was worth 1% of the overall module grade. During the synchronous live session, students were involved in small group exercises focused on application of knowledge from the asynchronous materials. Some of these exercises included designing a bioreactor, creating workflows of experimental procedures, analyzing datasets, troubleshooting hypothetical problems with therapeutic protein design. This was facilitated over MS Teams. Students were randomly selected to work in small groups. Separate '*channels*' were created in the MS Teams meeting to enable these groups to work independently. The lecturer could then jump in and out of each channel to monitor student progress and help drive discussions.

For 3rd year Pharmaceutical Biotechnology, asynchronous materials (pre-recorded narrated PowerPoint videos, notes and outside reading) were made available 5 days ahead of the timetabled contact hours for the module (Friday morning 09.00 – 12.00). Students reviewed the asynchronous materials at their own pace and then completed a 10- minute MCQ before joining a synchronous live session hosted over MS Teams. This synchronous session took place in during the 3rd timetabled hour for the module (11.00 – 12.00) and focused on knowledge application and small group exercises.

Figure 2: Flipped Classroom Design



2.4 Analysis of Student Engagement.

Student engagement with asynchronous lectures could be determined though the Moodle VLE. By applying the '*heatmap*' block to the relevant module page, information such as the total number of views on a recorded lecture URL, as well as the number of distinct student users that accessed the resource could be visually displayed as a colour coded map on the VLE module page (https://docs.moodle.org/402/en/Heatmap_block). Student engagement with asynchronous lecture recordings could then be normalized over each week of the semester by calculating a ratio of average video views / number of distinct student users that accessed the recording. This information could then be visually summarized in heatmaps as shown in Figure 3. Weekly MCQ scores could also be determined through the VLE. These scores, along with each student end of semester final exam score, could then be tabulated alongside the average video views for each student. Correlation between these variables was then determined using a Spearman analysis in GraphPad Prism software (version 9). In correlation analysis, p values

<0.05 were taken to be statistically significant.

2.5 Focus Groups.

At the end of the semester, students were invited to share their thoughts on the flipped classroom model via an anonymous, 50-minute focus group. The focus group was approved by the DkIT School of Health & Science Ethics Board (see below for a list of approved focus group questions). The focus group was hosted over MS Teams by a member of the DkIT faculty who was not involved in any aspect of the design, delivery, or assessment of the Pharmaceutical Biotechnology module. Out of 34 students enrolled in the module, 4 volunteered to participate in the focus group. Focus group data was thematically analyzed using coding methods in Microsoft Excel as previously described (Bree & Gallagher, 2016).

2.5.1 Focus group questions.

1. How much time did you spend engaging with the pre-recorded (asynchronous) material each week?
2. What factors (these can include factors outside college life) would affect the amount of time you engaged with the pre-recorded (asynchronous) material each week?
3. In what ways did you engage with the pre-recorded (asynchronous) material? (Watch passively, rewatch difficult parts, take notes?)
4. Would you have preferred if more / all lectures and tutorials were delivered asynchronously (pre-recorded for students to view in their own time)?
5. How often did you attend the weekly live lectures or tutorials (synchronous) each week?
6. What factors (these can include factors outside college life) would affect whether or not you attended the live lectures (synchronous) each week?
7. Would you have preferred if more lectures and tutorials were delivered synchronously (live at a fixed time)?
8. Would you have preferred if all lectures and tutorials were delivered synchronously (live at a fixed time)?
9. Did completing the weekly 10 minute multiple choice quizzes encourage you to engage with the pre-recorded lectures?

10. Did applying your knowledge in the weekly live sessions encourage you to engage with the pre-recorded lectures?
11. If the weekly 10 minute multiple choice quizzes were worth less marks, would you be less encouraged to complete them?
12. If the weekly 10 minute multiple choice quizzes were worth less marks, would you be less encouraged to engage with the pre-recorded lectures?
13. If the weekly 10 minute multiple choice quizzes were worth less marks, would you be less encouraged to engage with the live lectures or tutorials?
14. Please provide any feedback (positive or negative) on your experience with any or all of the class delivery or assessment methods listed above.

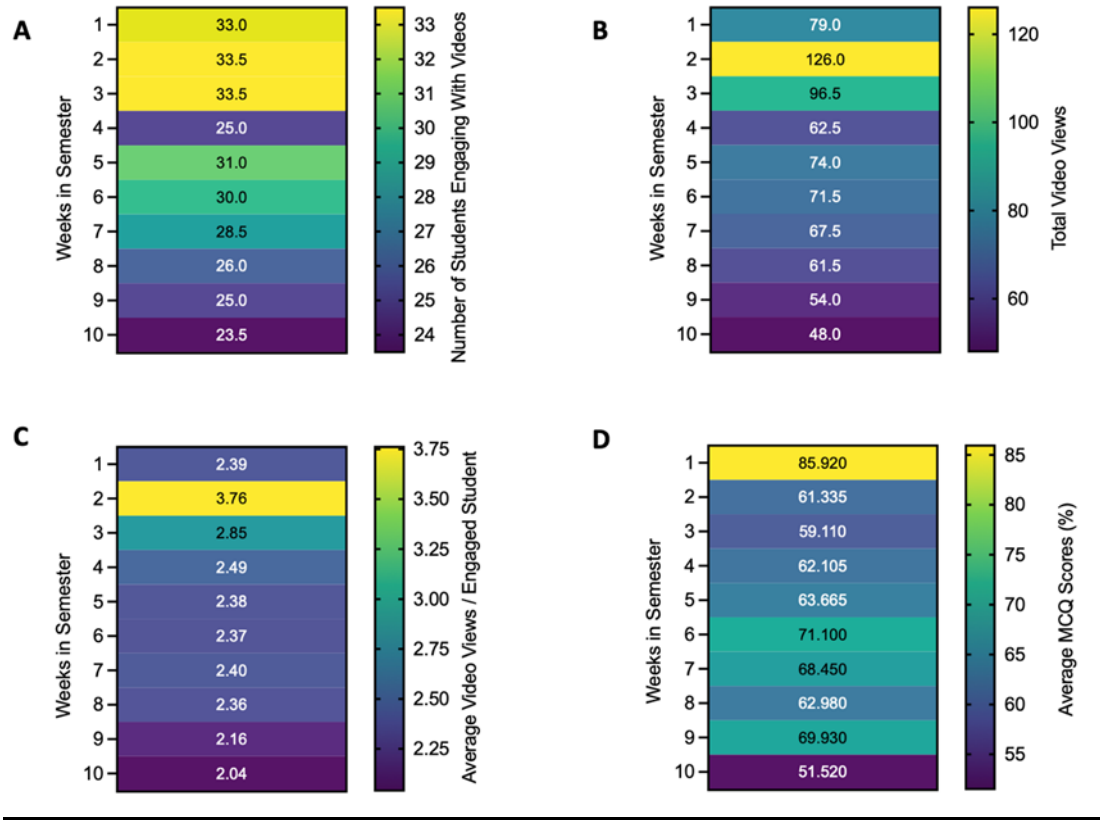
3. Results.

The data shown in Fig. 3A&B illustrate heatmaps of student engagement with asynchronous recorded lectures in the Pharmaceutical Biotechnology module. These heat maps show the number of weeks in the semester on the left y-axis (1-10) and the average number of distinct student users that accessed the recorded lecture URLs (2 per week) at least once on the right y-axis (Fig. 3A), or the number of times the recorded lecture videos were watched each week (Fig. 3B). These data show that at the beginning of the semester, almost all students in the class accessed the asynchronous lectures at least once (average of 33 - 33.5 students in week 1-3, Fig. 3A). However, in week 4, the number of students that accessed asynchronous lectures dropped to 25. While there was some recovery in week 5-6, the number of students that accessed asynchronous lectures steadily declined until the end of the semester. Across the whole semester, on average 28.9 students viewed recorded lecture videos at least once each week. Similarly, as shown in Fig. 3B, the total number of times asynchronous lectures were accessed peaked during week 2 and then steadily declined after week 5, reaching a low of only 48 views in week 10.

To normalize these two variables, the number of times asynchronous lectures were accessed was divided by the number of distinct student users each week (shown as ‘Engaged Student’ in Fig. 3C). These normalized data displayed a similar pattern as Fig.3A&B, where the most engagement with asynchronous lectures occurred in week 2 before steadily declining (although it should be noted that the severity of decline after week 2 was not as pronounced for the

normalized data in Fig. 3C as was observed for the absolute raw data in Fig. 3A&B). Across the whole semester, on average each distinct student user viewed each recorded lecture video 2.5 times. When the MCQ scores were calculated each week (completed immediately prior to the live synchronous class), as shown in Fig. 3D, the highest average score across the class was 85.9% in the first week, and this then decreased to a relatively stable range of 59.1 - 69 % between week 2 and 9 before dropping again to 51.5 % in week 10.

Figure 3: Student Engagement with Asynchronous Lectures.

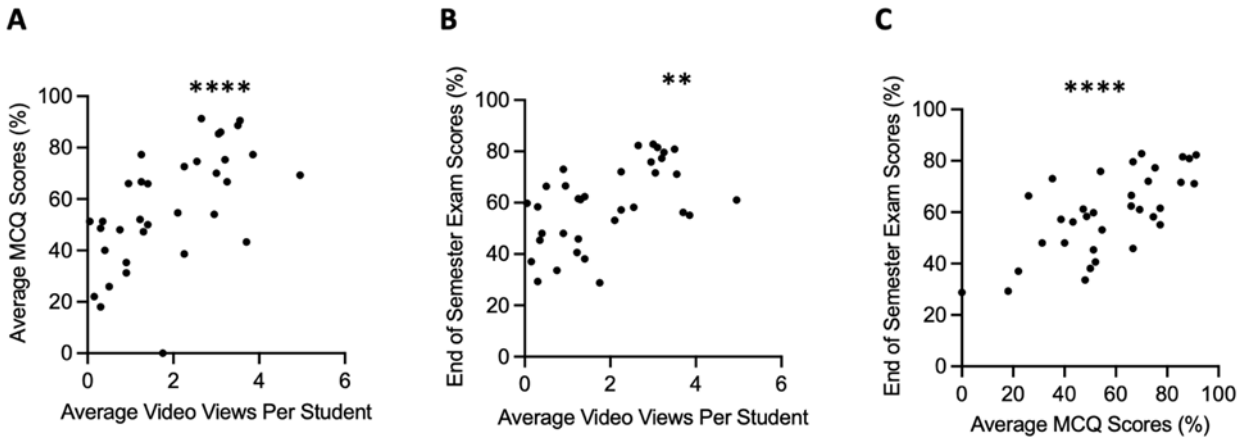


A Heatmap of the number of distinct student users that accessed asynchronous recorded lectures on Moodle for the Pharmaceutical Biotechnology module (Right y-axis). Left y -axis shows the number of weeks in the semester. Actual values are displayed within the heatmap itself (averaged for 2 lectures each week). **B** Heatmap of the number of times asynchronous recorded lectures were viewed on Moodle for the Pharmaceutical Biotechnology module (Right y-axis). Left y -axis shows the number of weeks in the semester. Actual values are displayed within the heatmap (averaged for 2 lectures each week). **C** Heatmap of the number of times asynchronous recorded lectures were viewed normalized to the number of distinct student users (Right y-axis). Left y -axis shows the number of weeks in the semester. Actual values are displayed within the heatmap (averaged for 2 lectures each week). **D** Heatmap of average

MCQ scores each week. Actual values are displayed within the heatmap (averaged for 2 lectures each week).

The average MCQ score for each student across the entire semester was then plotted against that student's average lecture video views across the entire semester. This allowed us to determine using a Spearman correlation analysis that these variables were indeed related (i.e., the more times students viewed recorded lecture videos, the better they tended to perform in the weekly MCQ assessments (Fig. 4A, $p<0.0001$, $n= 34$). Interestingly, this was also true when a student's average lecture video views were compared with their summative, end of semester exam scores as shown in Fig. 4B. This also displayed a positive correlative relationship, in that on average, the more times students viewed the recorded lectures, the better they tended to perform in their summative assessment (Fig. 4B, $p<0.01$, $n=34$). The performance in the summative, end of semester exam was also correlated with each students average weekly MCQ score, as shown in Fig. 4C ($p<0.0001$, $n=34$).

Figure 4: Student engagement with asynchronous lectures is correlated with assessment performance.



A Correlation analysis of each student average MCQ score across the semester against their average number of lecture video views each week. **B** Correlation analysis of each student final exam score against their average number of lecture video views each week. **C** Correlation analysis of each student average MCQ score across the semester against each student final exam score. 34 students were represented in each dataset. (** $p<0.01$, **** $p<0.0001$).

While the above data was interesting, it was not unexpected that students who watched the recorded lecture videos more often also performed better in the weekly MCQ assessments, which were based on this material, or on their end of semester final exam. Importantly, there

were key piece of information that we could not determine from this quantitative information. For example, the data from the VLE only told us how many times a student viewed a recorded lecture. We did not know how students watched the videos (in the background, paused to take notes, repeated certain sections etc.), thus a simple number of views, while correlated with assessment performance did not tell the entire story. Similarly, we could not discern how these videos or MCQ assessments might have impacted student engagement with live sessions (determining live student attendance with MCQ score or number of video views was not in our approved ethical remit). Thus, in order to more fully discern how and why students engaged with the asynchronous materials in the manner they did, we decided to ask students to explore these topics as part of a focus group.

At the conclusion of semester 1 2020, students within the 3rd year Pharmaceutical Biotechnology module were invited to participate in an anonymous online focus group as described in the Methods. 4 students participated in the 50-minute focus group and shared their experiences on module delivery. From these interactions, 4 key themes emerged from the student experience.

1. Asynchronous delivery enabled flexible learning and self-pacing for students, with the ability to replay lectures a noted benefit.
2. Synchronous learning allowed valuable class interaction, instructor feedback and knowledge application.
3. Combination of asynchronous and synchronous approaches was preferred over one mode of delivery alone.
4. Participation in synchronous sessions and low-stake weekly MCQs were an incentive to engage with asynchronous class materials.

Theme 1: Asynchronous delivery enabled flexible learning and self-pacing for students, with the ability to replay lectures a noted benefit.

The ability to pause, rewind and replay asynchronous recorded lectures was viewed as beneficial for students, as shown in the selected quotations below. Interestingly, 2 students noted that this ability meant they spent far more than the allotted 2 x hours of timetabled time to these resources.

- "*I found it really useful, actually, to be able to just pause the lectures and kind of that was our base information*."

- "*I think it's better that you can stop, go back over and listen to something several times*."
- "*Even if there were maybe two videos that were about 50 minutes each, I would spend well over 2 hours on that because you do kind of tend to pause it and take notes and go over something again*."
- "*You'd have to pause it for a while and just take it in then the next side wouldn't. So you just go speeding through it*."
- "*The pre-recorded videos were what took the longest, and the live lectures were kind of just based on what you learned from your pre-recorded videos. But in a week. I could spend, like it varies, but probably from 4 hours to 5 hours on both pre-recorded and live recorded*."

When asked what factors contributed to these perceptions, many students reflected that everyday responsibilities meant the ability to pause and replay lecture videos helped them get through their course under lockdown conditions. However, this same flexibility also meant that students were responsible for timetabling their own learning and it was sometimes difficult to balance this with other demands on their time. This often resulted in watching / reading the asynchronous resources in the evening or leaving it until the actual timetabled contact hours on Friday morning.

- "*The only time I had available to watch those videos was in the timetabled class on the Friday morning, because obviously the rest of the week we have other things to do*."
- "*I think the recorded lectures were harder to schedule. Let's say simply because you allow or people allow other stuff to creep into their life*."
- "*So around the house are having responsibilities at home. You would be more inclined to put back the recorded lecture until later in the evening*."
- "*I'm giving family lifts constantly during the day. So most of the time I always do them in the evening*."

Theme 2: Synchronous learning allowed valuable class interaction, instructor feedback and knowledge application.

The synchronous classes held during the 3rd timetabled hour were noted as being valuable opportunities for students to get feedback from their instructor. Interestingly, some students

noted the student-student interactions or teamwork aspect of a synchronous space, with one student noting that "*if anyone was completely lost, we'd be able to have a chat with them*", suggesting that the synchronous sessions facilitated peer-learning and support. Furthermore, another student highlighted that the synchronous sessions "*kind of feel like a little bit, like in the class environment*". The application of knowledge was also marked as being particularly useful in these live sessions, with one student describing how it helped them in examination preparation.

- "*I like the kind of application where you have a couple of slides of questions, and if you were designing a bio reactor for this kind of thing, what technique would you use, to get you thinking about what we covered up until then found that really helpful*."
- "*We would have the live sessions for kind of a bit of feedback, or if we had any questions just as a quick, if anyone was completely lost, we'd be able to have a chat with them then*."
- "*The live session, you're looking forward to getting in there and actually working through stuff, maybe working as a team and applying the stuff that you should have done*."
- "*I liked having a session that we could talk about it and kind of apply it in the sense of how it appeared in an exam*."
- "*I feel like the way it was done because you can really just have a conversation with the lecturer to go through the problem during the live session*."
- "*I enjoyed the live sessions as well because I thought they were quite interactive and we got the opportunity to all kind of feel like a little bit, like in the class environment*."

Theme 3: Combination of asynchronous and synchronous approaches was preferred over one mode of delivery alone.

When asked specifically whether the Pharmaceutical Biotechnology module should have been taught exclusively synchronously or asynchronously, student respondents unanimously stated that a mix of both was better. Some students elaborated on this point, highlighting that the 2:1 ratio of asynchronous: synchronous classes worked well and that increasing the number of live classes would have been "*too much*". The mixed delivery approach was advantageous for many students as they were still able to balance their outside college responsibilities while still having regular, meaningful engagement with their instructor and peers.

- "*The mix personally, the mix simply because being at home, if I'm at home, I get interrupted during the day. Whereas if I'm in college, people can't come into the house because I'm not here*."
- "*I think the proportions are good as well that we have essentially recorded and then we have essentially two thirds recorded and one third live. I think that works really well, actually. I think if it was half and half, that would almost be a bit too much live*."
- "*I think the balance was really good with online and live and recorded*."

Theme 4: Participation in synchronous sessions and low-stake weekly MCQs were an incentive to engage with asynchronous class materials.

When students were asked how participation in the live classes or the regular MCQs influenced their engagement with the asynchronous lecture recordings, we received several interesting responses. One student remarked that during the live classes there was knowledge application, which often involved Q&A with the instructor, this meant that they were incentivized to engage with the asynchronous content to ensure they were properly equipped to answer any question.

While each MCQ was only worth 1% of their overall module grade, as this summated to a total of 10% over the semester this provided sufficient motivation for students to study asynchronous materials. One student stated, "*It was definitely nice to know that you're kind of building up a few marks as you go, not just tiny percentages, but that it was kind of contributing to a bit. You did feel that you got something out of it in terms of you've applied your knowledge*".

- "*I think the fact that there is then that one [live class] last week, it kind of encourages you to spend the other whatever 2 hours actually covering the content that's going to be talked about in the live because otherwise you're going in and you don't have a clue. Like you don't want to be asked a question and not know. So you do tend to pressure yourself more to actually cover the content before the end of the week*."
- "*And even with the quizzes as well, if you're doing a quiz, you obviously have to know the content of what we learned that week to answer the questions correctly. So the quiz and also the live lecture has kind of pushed us to kind of like, we definitely have to get these videos done before the end of the week*."
- "*The few percent [MCQ] does help. It makes you focus a little bit more because you can kind of go well, you know, have I engaged with the weeks material? Yes. Does that reflect on the mark? Yes, it does. And then that contributes then to your overall. And that's*

probably what pushed me or helped me certainly pass that module."

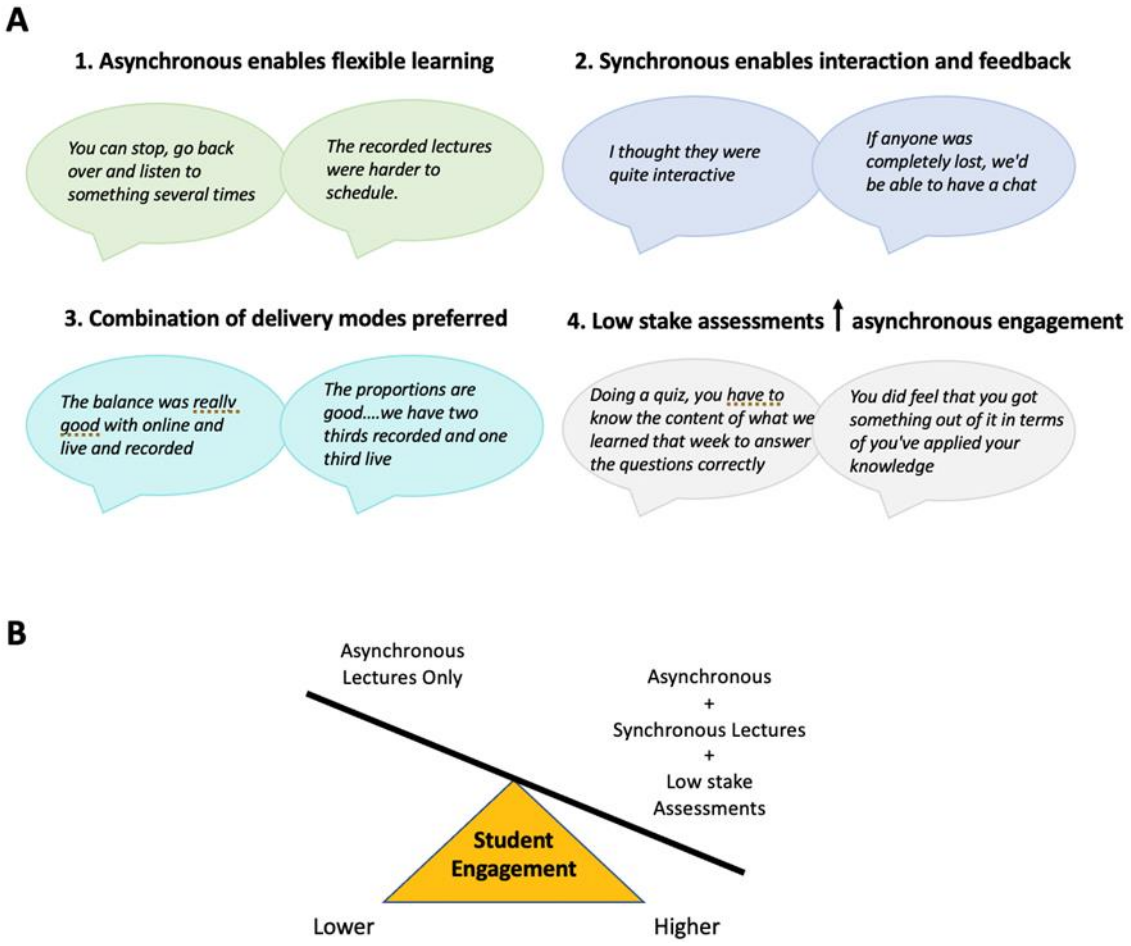
- "*It was definitely nice to know that you're kind of building up a few marks as you go, not just tiny percentages, but that it was kind of contributing to a bit. You did feel that you got something out of it in terms of you've applied your knowledge, but also you're working your way towards your final mark as well*."

An interesting comment from one student suggested engaging with the asynchronous material and completing the weekly MCQ, not only helped with their summative mark but may also be used as a formative self-assessment to know if they had adequately engaged with the weekly material or not. "*It makes you focus a little bit more because you can kind of go well, you know, have I engaged with the weeks material? Yes. Does that reflect on the mark? Yes, it does. And then that contributes then to your overall.*"

At one point in the focus group, students were asked would they still have completed the MCQs if they were worth less marks. One student replied, "*I think it would have. I think I would have used it as a way to go over*." However, another student expressed a contrasting sentiment, "*You won't be inclined to do the quiz at all because it will be seen as it's only 1%. However, the quiz is 10% at the end of the day*." Thus, it appears that certain students would be less inclined to complete the MCQs (and possibly engage with asynchronous materials) if the allocated marks were lower. However, this student noted that the quizzes might still have been a useful formative revision tool, even if they were not completed for marks. This was echoed by another student who stated, "*I would just be using it as a study tool at the end of the semester. I wouldn't even bother during the week [if they were worth less marks]*."

A summary of the qualitative results and possible implications is shown in Fig. 5.

Figure 5: Conclusion.



A summary of the 4 key themes identified from our focus groups from the Pharmaceutical Biotechnology module with representative student quotes. B Our findings suggest that a combination of synchronous and asynchronous classes, with regular low-stake assessments can increase student engagement with asynchronous online material compared to asynchronous classes alone.

4. Discussion.

In this paper, we describe the implementation of an online flipped classroom for a 3rd year Pharmaceutical Biotechnology module at Dundalk Institute of Technology. We utilized a mixed asynchronous and synchronous delivery model that included regular low-stake assessments. Our initial data showed that student engagement with asynchronous recorded lectures steadily decreased throughout the semester, and the level of student engagement (determined by the number of average video views each week) was positively correlated with performance in weekly low-stake MCQ quizzes and also in summative end of semester exams. However, in

order to determine how and why students viewed the asynchronous materials (incentives, motivational factors, length of time spent on materials, replays, note taking, etc), we needed students to relay their experiences in more detail through focus groups. Qualitative data from such a student focus group indicated that low-stake assessments, and participation in the synchronous application classes motivated students to increase engagement with asynchronous, pre-recorded lectures. These findings have pedagogical implications for educators designing future modules or programmes for online delivery.

The potential benefits of online asynchronous vs synchronous learning have been widely reported in the pedagogical literature, and this has accelerated with the increased use of online 3rd level education due to the COVID-19 pandemic. While some groups have found that one mode may be preferred by students over another, these findings are not consistent. For example, while some studies report no statistical difference in summative examination scores between asynchronous or synchronous online delivery (Farros et al., 2020; Moridani, 2007; Schoenfeld-Tacher & Dorman, 2021; Suliman et al., 2022), others have found that examination performance or student perceptions are positively impacted by either synchronous delivery (Kositanurit et al., 2022; Yadav et al., 2021) or asynchronous delivery (Buxton, 2014). However, one consistent fact in the literature is that both forms of delivery alone struggle with engaging students in online learning (Hrastinski, 2008; Khan, Atta, Sajjad, & Jawaid, 2021; Northey, 2015; Peterson, 2018; Rhim & Han, 2020; Serhan, 2020). Several studies have found that mixed asynchronous and synchronous delivery is optimum for online student learning and engagement (Moridani, 2007) and that flipped classes are useful for structuring this integrated delivery (Chesterton et al., 2022; Rehman & Fatima, 2021).

Flipped classrooms are a form of active learning, and its possible benefits over traditional classroom teaching have been expounded in the literature. These benefits include increasing student engagement, increasing summative examination scores and increasing student retention (Gopalan et al., 2022; Hernandez-Guerra et al., 2021; Nouri, 2016; Rathner & Schier, 2020; Sultan, 2018; Tassabehji, Banasr, Hamza, & Dragan, 2021). For our 3rd year Pharmaceutical Biotechnology module, we uploaded 2 hours of pre-recorded lecture materials, along with PowerPoint decks and outside reading resources to a VLE 5-days before a live online class over MS Teams. During this live class, students would work in small groups to complete active, application exercises based on that week’s asynchronous materials. Immediately prior

to each week's synchronous application class, students completed a 10-minute MCQ worth 1% of their total module grade.

We sought to allow students an element of control with their own learning in the flipped classrooms with asynchronous materials, which they could progress through in their own pace. We utilized a 2:1 ratio of asynchronous to synchronous materials in our flipped classroom. However, students reported that as they could pause, rewind, and replay the recorded lectures they often spent far longer than the allotted 2 hours with these resources. The ability to self-pace was a strong benefit of asynchronous learning from our study, and this has also been reported by other groups (Chesterton et al., 2022; de Jong et al., 2013; Fabriz, Mendzheritskaya, & Stehle, 2021; van der Keylen, Lippert, Kunisch, Kuhlein, & Roos, 2020).

To make students feel competent in the material, we utilized low-stake assessments in the form of weekly MCQs worth 1% of their total grade (for a total of 10% over 10 weeks). As evidenced from the focus group feedback shown in the results, not only did these quizzes help students engage with asynchronous materials but they also were used by students as a form of formative assessment. A comment from student exemplifies this "*Have I engaged the week material? Yes. Does that reflect on the mark? Yes, it does*." This suggests that these quizzes were used as a formative feedback tool by students to gauge their competency after reviewing asynchronous materials. Therefore, by engaging with the material more, they felt more competent going forward. Thus, quizzes fulfilled multiple roles in the flipped classroom. They were a summative incentive to engage with the asynchronous materials (evidence from focus group feedback), they could be used as a formative feedback tool by students and as information retrieval is a vital element of consolidating learning (Karpicke & Roediger, 2008), they could also be used as a revision tool.

We attempted to bring about interaction in our flipped classroom through live application classes, in which students worked in small groups to solve active problem sets related to that week's asynchronous materials. One of the major downsides with solely asynchronous online learning is a lack of students sense of belonging (Peterson, 2018) and lack of student-student or student-instructor interactions (Gadbury-Amyot & Brockman, 2011; Holzmann-Littig et al., 2022; Schoenfeld-Tacher & Dorman, 2021). Social interactions can be encouraged in solely asynchronous online delivery through asynchronous discussion boards, which are reported to boost student engagement and course satisfaction (Osborne, Byrne, Massey, & Johnston, 2018; Wiecha, Gramling, Joachim, & Vanderschmidt, 2003). However, in our mixed approach we

sought to maximize student-student interactions in the small group work during the live synchronous classes as has been reported previously (Rapanta, 2020). Our focus group indicated that students appreciated these opportunities, with one student highlighting that it was "*like in the class environment*", highlighting that this aspect was missing from the asynchronous content. Furthermore, the live sessions provided opportunities for peer-peer learning with one student commenting "*if anyone was completely lost, we'd be able to have a chat with them*", suggesting that elements of teamwork and student collaboration and support were also fostered in the synchronous classes that might have been impossible if students only engaged with the asynchronous content alone.

A key piece of data from our focus group was that low-stake MCQs and synchronous classes did in fact encourage students to engage more fully with the asynchronous online materials. For the live classes, students reported that as they knew they would have to answer questions and work on problems related to that week's materials, there was an onus to engage with the recorded lectures so that they were adequately prepared to answer questions. The fact that the MCQs were worth marks that contributed to the overall grade also provided an incentive for students to engage with the asynchronous materials. Interestingly, when students were asked if they would have still completed the MCQs if they were worth less marks, some students stated they would not have completed them every week but would instead have used them as a revision tool at the end of the semester. Thus, it seems that even if small assessments do not provide sufficient marks to warrant regular engagement, they can still be useful study resources for students.

In a similar study to our own, (Gopalan et al., 2021) utilized a flipped classroom model in a graduate physiology course, using a combination of asynchronous materials (recorded lectures and tutorial videos) and synchronous online classes on Zoom. Small group discussions were facilitated using breakout rooms, and students completed a short formative assessment during live sessions. Like our findings, this study reported that the integrated flipped classroom was positively received by students and this study found that student summative academic performance (assessed by a quiz at the beginning vs end of the semester) was increased by this model. Student feedback from this study noted that the quizzes were "liked" by students, but there was no analysis as to how the live classes or formative quizzes might have specifically affected asynchronous engagement. In another physiology course, (Beason-Abmayr et al., 2021) also used a flipped classroom over Zoom, where students had access to asynchronous materials before engaging in an MCQ prior to a live synchronous, application class. In this

instance, the course was already flipped prior to the COVID-19 pandemic and the authors noted that this eased the transition from face-to-face to online teaching. This study did not assess how the MCQs during the synchronous sessions impacted student engagement, but this study did highlight that students were more comfortable interacting with each in small groups in the breakout rooms than on a large Zoom call during live classes. Anecdotally, we experienced similar trends in our own flipped classes, where students were reluctant to voluntarily answer questions or raise discussion points in the open MS Teams application classes but were far more likely to interact with each other in the small group exercises. This has also been reported for physiotherapy students in the UK where engagement and interaction in online synchronous classes was increased when students were split into small groups, or when short quizzes or breakout rooms were used to diversify the application tasks (Chesterton et al., 2022).

4.1 Limitations & Future Work.

While intriguing, our findings in this study are quite preliminary. The low number of students that participated in our focus group means that any conclusions drawn from their recollections should not be interpreted as the totality of the student experience with our model. In a future study on a similar module, a longitudinal analysis across multiple modules and years should be examined.

Our findings suggest that in future course and module design, the use of flipped classrooms that combine regular low-stake assessments with live application classes involving small group work can increase student engagement. This will become increasingly relevant in a post-COVID educational landscape as the impetus for 3rd level institutions to develop and deliver online courses will continue to increase. Furthermore, our findings have implications for not only online but also face-to-face flipped classroom teaching. In undergraduate settings, the engagement with asynchronous materials for flipped classrooms (either face-to-face or online) can be difficult to encourage, or even assess or monitor (Gopalan et al., 2022). Our study suggests that group application exercises in a synchronous setting or low-stake assessments (or combination) might increase engagement.

5. Conclusion.

While our findings are preliminary, due to the low number of students (4/34) that contributed to our focus group, our data does suggest that combining asynchronous and synchronous

resources and low-stake assessments might enhance student engagement with online asynchronous classes (Fig. 5). These findings have pedagogical implications for educators designing future modules or programmes for online delivery.

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